

# LINEAR INTEGRATED CIRCUITS

## Sealed Lead-Acid Battery Charger

UC2906  
UC3906

### FEATURES

- Optimum control for maximum battery capacity and life
- Internal state logic provides three charge states
- Precision reference tracks battery requirements over temperature
- Controls both voltage and current at charger output
- System interface functions
- Typical standby supply current of only 1.6mA

### DESCRIPTION

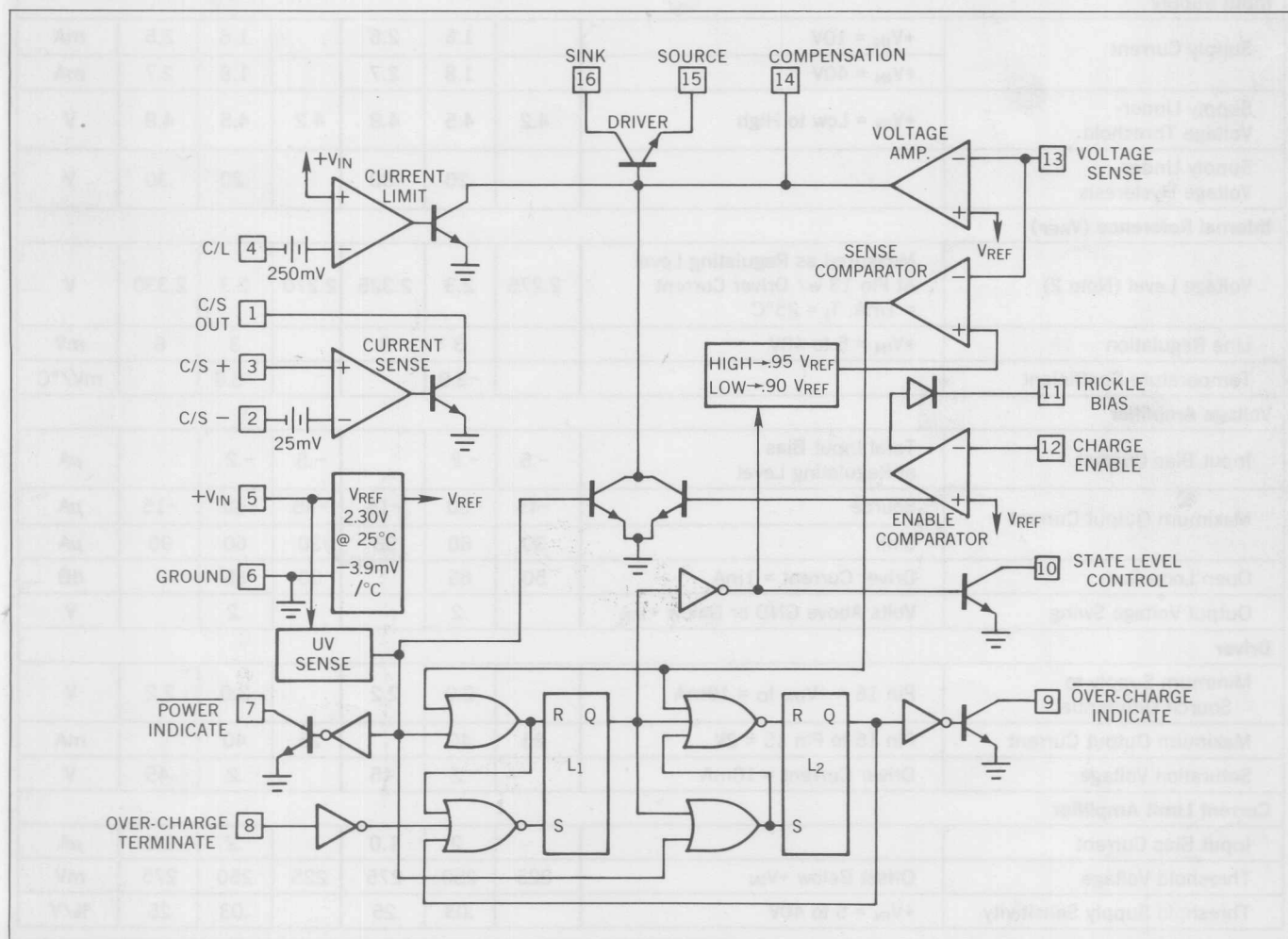
The UC2906 series of battery charger controllers contains all of the necessary circuitry to optimally control the charge and hold cycle for sealed lead-acid batteries. These integrated circuits monitor and control both the output voltage and current of the charger through three separate charge states; a high current bulk-charge state, a controlled over-charge, and a precision float-charge, or standby, state.

Optimum charging conditions are maintained over an extended temperature range with an internal reference that tracks the nominal temperature characteristics of the lead-acid cell. A typical standby supply current requirement of only 1.6mA allows these ICs to predictably monitor ambient temperatures.

Separate voltage loop and current limit amplifiers regulate the output voltage and current levels in the charger by controlling the onboard driver. The driver will supply up to 25mA of base drive to an external pass device. Voltage and current sense comparators are used to sense the battery condition and respond with logic inputs to the charge state logic. A charge enable comparator with a trickle bias output can be used to implement a low current turn-on mode of the charger, preventing high current charging during abnormal conditions such as a shorted battery cell.

Other features include a supply under-voltage sense circuit with a logic output to indicate when input power is present. In addition the over-charge state of the charger can be externally monitored and terminated using the over-charge indicate output and over-charge input.

### UC2906 BLOCK DIAGRAM

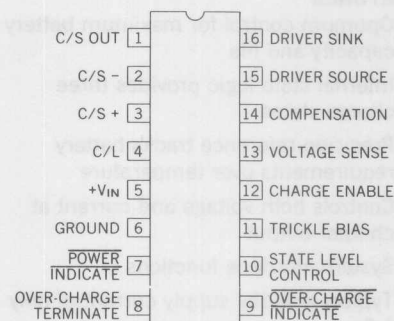


**ABSOLUTE MAXIMUM RATINGS** (Note 1)

Supply Voltage (+V <sub>IN</sub> )	40V
Open Collector Output Voltages	40V
Amplifier and Comparator Input Voltages	-0.3V to +40V
Over-Charge Terminate Input Voltage	-0.3V to +40V
Current Sense Amplifier Output Current	40mA
Other Open Collector Output Currents	5mA
Trickle Bias Output Current	-40mA
Driver Current	40mA
Power Dissipation at T <sub>A</sub> = 25°C	
Derate at 10mW/°C Above T <sub>A</sub> = 25°C	1000mW
Power Dissipation at T <sub>C</sub> = 25°C	
Derate at 16mW/°C Above T <sub>C</sub> = 25°C	2000mW
Thermal Resistance, Junction-to-Ambient	100°C/W
Thermal Resistance, Junction-to-Case	60°C/W
Operating Junction Temperature	-55°C to +150°C
Storage Temperature	-65° to +150°C
Lead Temperature (Soldering, 10 Seconds)	300°C

Note: 1. Voltages are referenced to ground (Pin 6).

Currents are positive into, negative out of, the specified terminals.

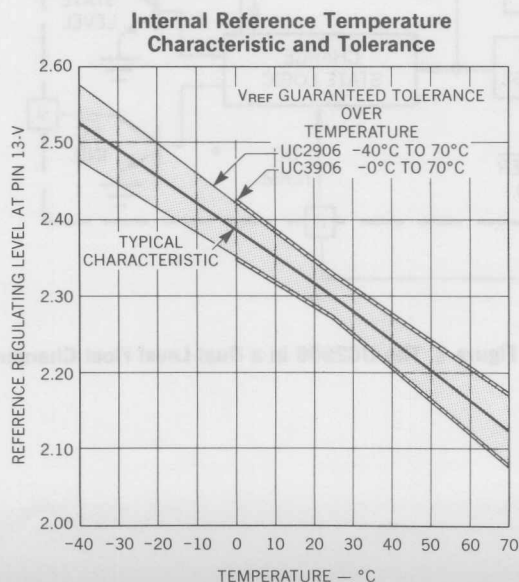
**CONNECTION DIAGRAM****DIL-16 (TOP VIEW)  
J or N PACKAGE****ELECTRICAL CHARACTERISTICS** (Unless otherwise stated, these specifications apply for T<sub>A</sub> = -40°C to +70°C for the UC2906 and 0°C to +70°C for the UC3906, +V<sub>IN</sub> = 10V.)

PARAMETER	TEST CONDITIONS	2906			3906			UNITS
		MIN.	TYP.	MAX.	MIN.	TYP.	MAX.	
Input Supply								
Supply Current	+V <sub>IN</sub> = 10V		1.6	2.5		1.6	2.5	mA
	+V <sub>IN</sub> = 40V		1.8	2.7		1.8	2.7	mA
Supply Under-Voltage Threshold	+V <sub>IN</sub> = Low to High	4.2	4.5	4.8	4.2	4.5	4.8	V
Supply Under-Voltage Hysteresis			.20	.30		.20	.30	V
Internal Reference (V <sub>REF</sub> )								
Voltage Level (Note 2)	Measured as Regulating Level At Pin 13 w/ Driver Current = 1mA, T <sub>J</sub> = 25°C	2.275	2.3	2.325	2.270	2.3	2.330	V
Line Regulation	+V <sub>IN</sub> = 5 to 40V		3	8		3	8	mV
Temperature Coefficient			-3.9			-3.9		mV/°C
Voltage Amplifier								
Input Bias Current	Total Input Bias at Regulating Level	-.5	-.2		-.5	-.2		μA
Maximum Output Current	Source	-45	-30	-15	-45	-30	-15	μA
	Sink	30	60	90	30	60	90	μA
Open Loop Gain	Driver Current = 1mA	50	65		50	65		dB
Output Voltage Swing	Volts Above GND or Below +V <sub>IN</sub>		.2			.2		V
Driver								
Minimum Supply to Source Differential	Pin 16 = +V <sub>IN</sub> , I <sub>O</sub> = 10mA		2.0	2.2		2.0	2.2	V
Maximum Output Current	Pin 16 to Pin 15 = 2V	25	40		25	40		mA
Saturation Voltage	Driver Current = 10mA		.2	.45		.2	.45	V
Current Limit Amplifier								
Input Bias Current			.2	1.0		.2	1.0	μA
Threshold Voltage	Offset Below +V <sub>IN</sub>	225	250	275	225	250	275	mV
Threshold Supply Sensitivity	+V <sub>IN</sub> = 5 to 40V		.03	.25		.03	.25	%/V

Note: 2. The reference voltage will change as a function of power dissipation on the die according to the temperature coefficient of the reference and the thermal resistance, junction-to-ambient.

**ELECTRICAL CHARACTERISTICS** (Unless otherwise stated, these specifications apply for  $T_A = -40^\circ\text{C}$  to  $+70^\circ\text{C}$  for the UC2906 and  $0^\circ\text{C}$  to  $+70^\circ\text{C}$  for the UC3906,  $+V_{IN} = 10\text{V}$ .)

PARAMETER	TEST CONDITIONS		2906			3906			UNITS
			MIN.	TYP.	MAX.	MIN.	TYP.	MAX.	
Voltage Sense Comparator									
Threshold Voltage	As a Function of $V_{REF}$	$L_1 = \text{RESET}$	.945	.95	.955	.945	.95	.955	V/V
		$L_1 = \text{SET}$	.895	.90	.905	.895	.90	.905	V/V
Input Bias Current	Total Input Bias at Thresholds		-.5	-.2		-.5	-.2		$\mu\text{A}$
Current Sense Comparator									
Input Bias Current				.1	.5		.1	.5	$\mu\text{A}$
Input Offset Current				.01	.2		.01	.2	$\mu\text{A}$
Input Offset Voltage	Referenced to Pin 2, $I_{OUT} = 1\text{mA}$		20	25	30	20	25	30	mV
Offset Supply Sensitivity	$+V_{IN} = 5$ to $40\text{V}$			.05	.35		.05	.35	%/V
Offset Common Mode Sensitivity	$CMV = 2\text{V}$ to $+V_{IN}$			.05	.35		.05	.35	%/V
Maximum Output Current	$V_{OUT} = 2\text{V}$		25	40		25	40		mA
Output Saturation Voltage	$I_{OUT} = 10\text{mA}$			.2	.45		.2	.45	V
Enable Comparator									
Threshold Voltage	As a Function of $V_{REF}$		.99	1.0	1.01	.99	1.0	1.01	V/V
Input Bias Current			-.5	-.2		-.5	-.2		$\mu\text{A}$
Trickle Bias Maximum Output Current	$V_{OUT} = +V_{IN} - 3\text{V}$		25	40		25	40		mA
Trickle Bias Maximum Output Voltage	Volts Below $+V_{IN}$ , $I_{OUT} = 10\text{mA}$			2.0	2.6		2.0	2.6	V
Trickle Bias Reverse Hold-Off Voltage	$+V_{IN} = 0\text{V}$ , $I_{OUT} = -10\mu\text{A}$		6.5	7.0		6.5	7.0		V
Over-Charge Terminate Input									
Threshold Voltage			.7	1.0	1.3	.7	1.0	1.3	V
Internal Pull-Up Current	At Threshold			10			10		$\mu\text{A}$
Open Collector Outputs (Pins 7, 9 and 10)									
Maximum Output Current	$V_{OUT} = 2\text{V}$		3	5		3	5		mA
Saturation Voltage	$I_{OUT} = 1.6\text{mA}$			.25	.45		.25	.45	V
	$I_{OUT} = 50\mu\text{A}$			.03	.05		.03	.05	V
Leakage Current	$V_{OUT} = 40\text{V}$			1	3		1	3	$\mu\text{A}$



## Dual Level Float Charger Operation

The UC2906 is shown configured as a dual level float charger in Figure 1. All high currents are handled by the external PNP pass transistor with the driver supplying base drive to this device. This scheme uses the TRICKLE BIAS output and the charge enable comparator to give the charger a low current turn-on mode. The output current of the charger is limited to a low level until the battery reaches a specified voltage, preventing high current charging if a battery cell is shorted. Figure 2 shows the state diagram of the charger. Upon turn-on the UV sense circuitry puts the charger in state 1, the high rate bulk-charge state. In this state, once the enable threshold has been exceeded, the charger will supply a peak current that is determined by the 250mV offset in the C/L amplifier and the sensing resistor  $R_s$ .

To guarantee full re-charge of the battery, the charger's voltage loop has an elevated regulating level,  $V_{OC}$ , during state 1 and

state 2. When the battery voltage reaches 95% of  $V_{OC}$ , the charger enters the over-charge state, state 2. The charger stays in this state until the OVER-CHARGE TERMINATE pin goes high. In Figure 1, the charger uses the current sense amplifier to generate this signal by sensing when the charge current has tapered to a specified level,  $I_{OCT}$ . Alternatively the over-charge could have been controlled by an external source, such as a timer, by using the OVER-CHARGE INDICATE signal at Pin 9. If a load is applied to the battery and begins to discharge it, the charger will contribute its full output to the load. If the battery drops 10% below the float level, the charger will reset itself to state 1. When the load is removed a full charge cycle will follow. A graphical representation of a charge, and discharge, cycle of the dual level float charger is shown in Figure 3.

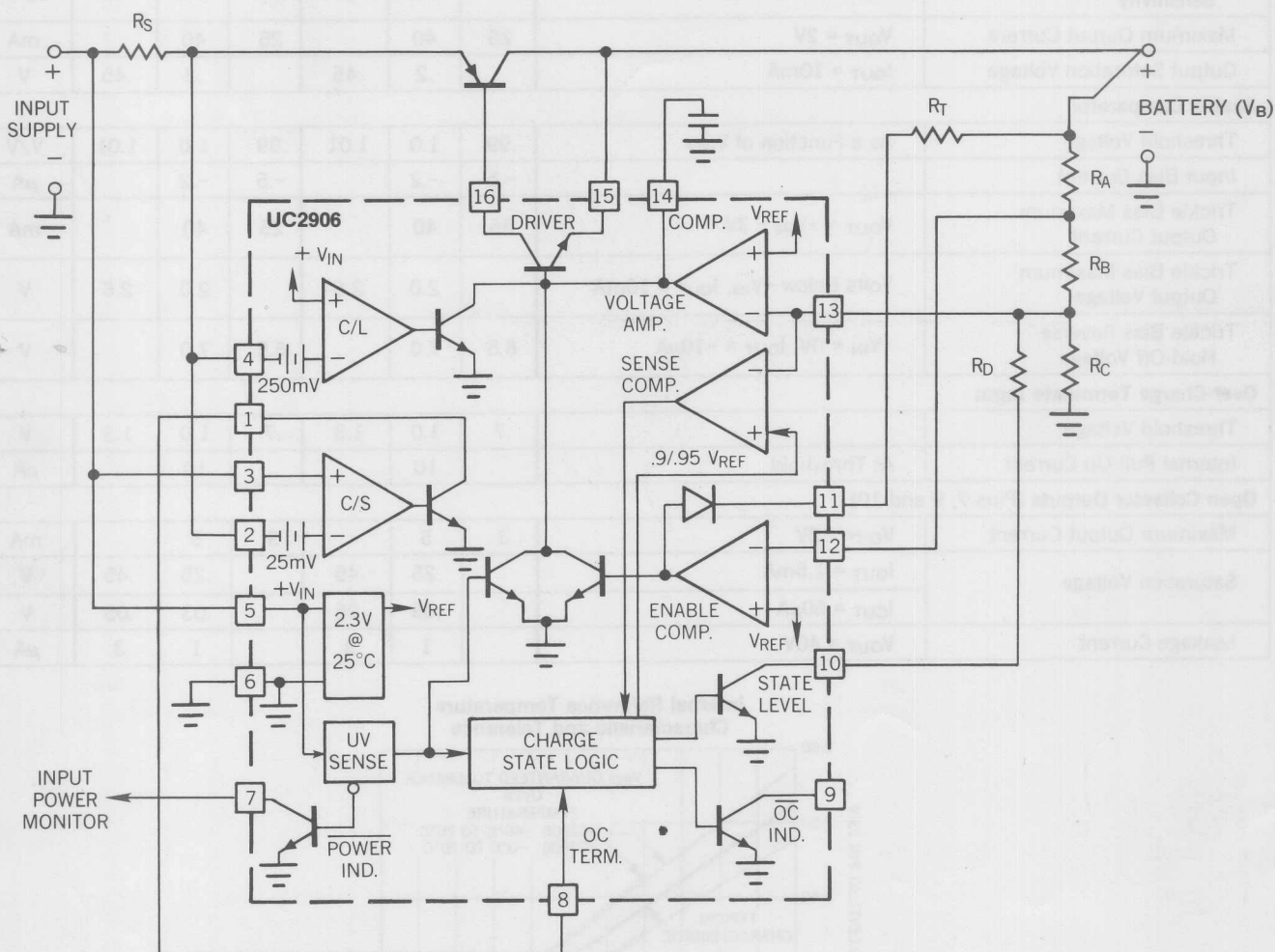
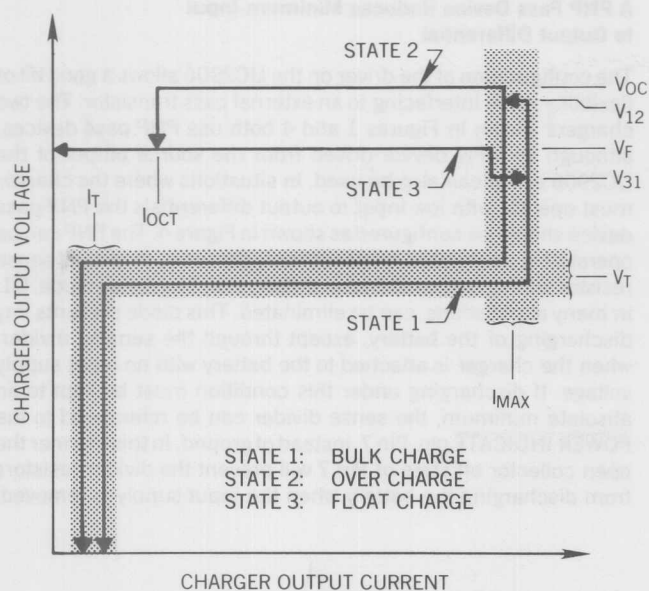


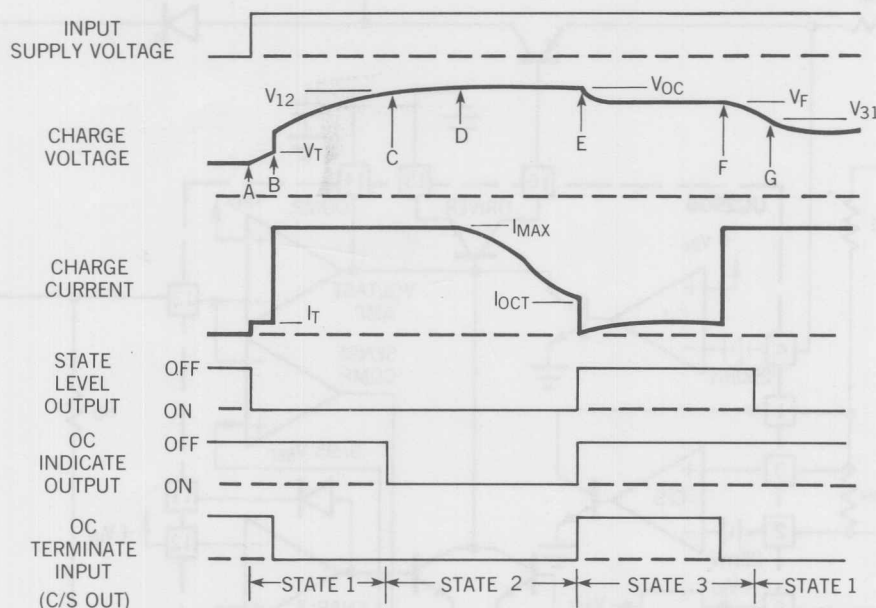
Figure 1. The UC2906 in a Dual Level Float Charger



- 1.)  $V_T = V_{REF} \left( 1 + \frac{R_A}{R_B + R_X} \right)$  Where:  $R_X = \frac{R_D R_C}{R_D + R_C}$
- 2.)  $V_{OC} = V_{REF} \left( 1 + \frac{R_A + R_B}{R_C} + \frac{R_A + R_B}{R_D} \right)$
- 3.)  $V_F = V_{REF} \left( 1 + \frac{R_A + R_B}{R_C} \right)$
- 4.)  $V_{12} = .95 V_{OC}$
- 5.)  $V_{31} = .9 V_F$
- 6.)  $I_{MAX} = \frac{.25V}{R_S}$
- 7.)  $I_{OC} = \frac{.025V}{R_S}$
- 8.)  $I_T = \frac{V_{IN} - V_B - 2.5V}{R_T}$

$V_F @ 12V = 2.35 / cell$   
 $V_{OC} = 2.45$   
 $V_F = 2.3$   
 $\approx 1.7V$

Figure 2. State Diagram and Design Equations For the Dual Level Float Charger



**Explanation: Dual Level Float Charger**

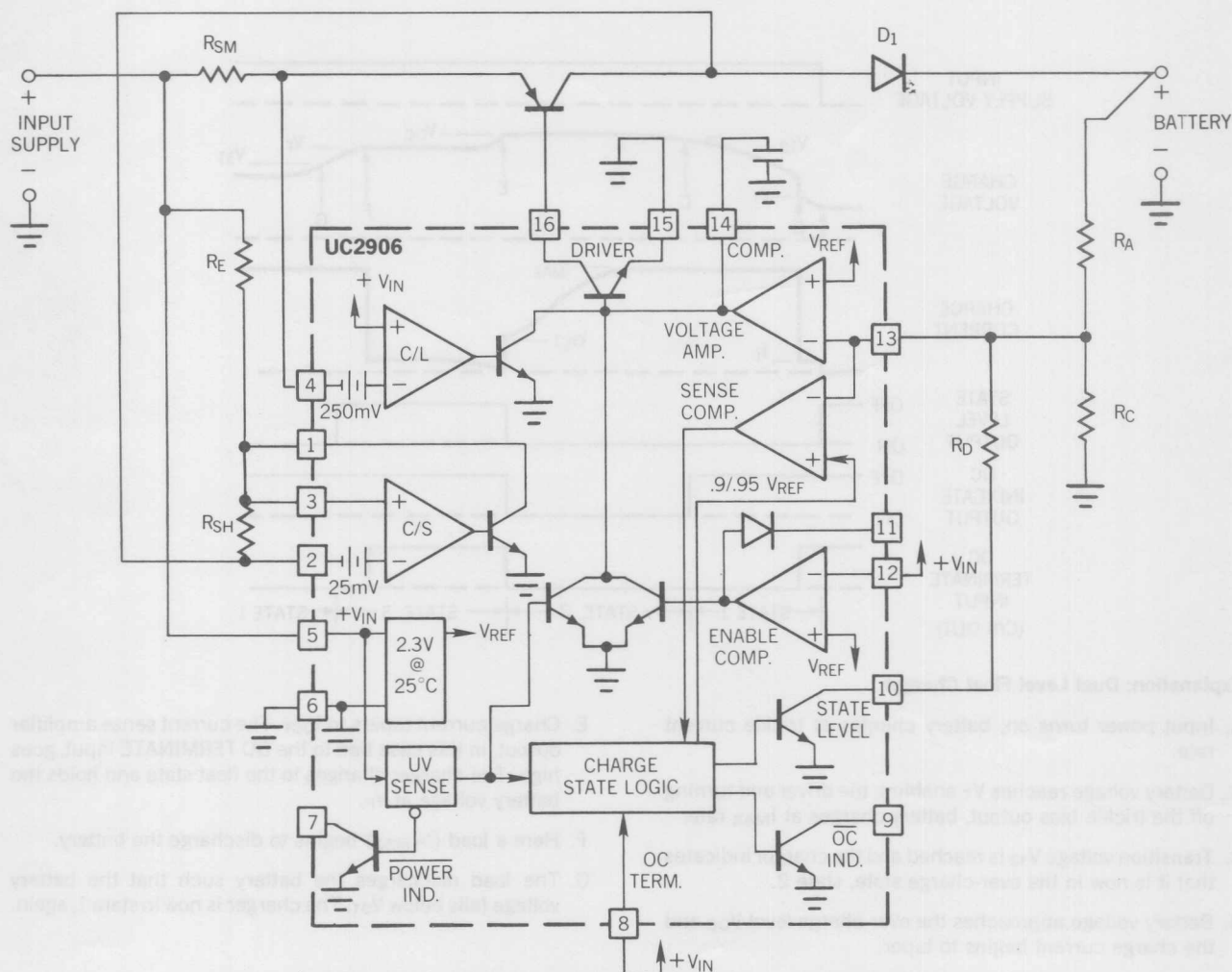
- A. Input power turns on, battery charges at trickle current rate.
- B. Battery voltage reaches  $V_T$  enabling the driver and turning off the trickle bias output, battery charges at  $I_{MAX}$  rate.
- C. Transition voltage  $V_{12}$  is reached and the charger indicates that it is now in the over-charge state, state 2.
- D. Battery voltage approaches the over-charge level  $V_{OC}$  and the charge current begins to taper.
- E. Charge current tapers to  $I_{OC}$ . The current sense amplifier output, in this case tied to the OC TERMINATE input, goes high. The charger changes to the float state and holds the battery voltage at  $V_F$ .
- F. Here a load ( $> I_{MAX}$ ) begins to discharge the battery.
- G. The load discharges the battery such that the battery voltage falls below  $V_{31}$ . The charger is now in state 1, again.

Figure 3. Typical Charge Cycle: UC2906 Dual Level Float Charger

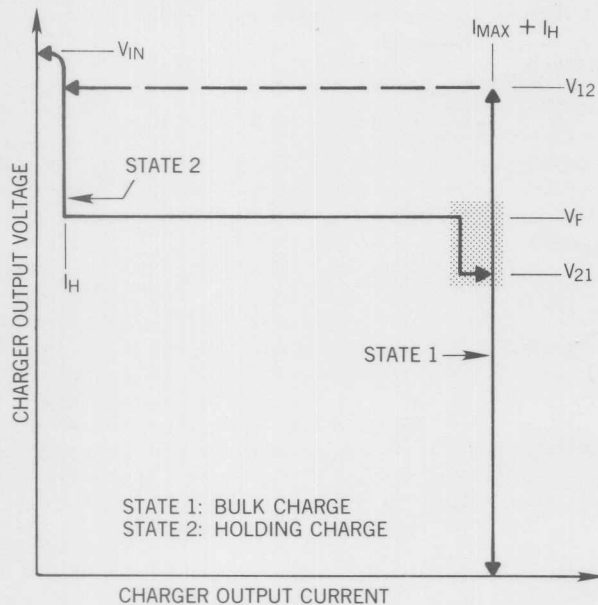
## A PNP Pass Device Reduces Minimum Input to Output Differential

The configuration of the driver on the UC2906 allows a good bit of flexibility when interfacing to an external pass transistor. The two chargers shown in Figures 1 and 4 both use PNP pass devices, although an NPN device driven from the source output of the UC2906 driver can also be used. In situations where the charger must operate with low input to output differentials the PNP pass device should be configured as shown in Figure 4. The PNP can be operated in a saturated mode with only the series diode and sense resistor adding to the minimum differential. The series diode, D1, in many applications, can be eliminated. This diode prevents any discharging of the battery, except through the sensing divider, when the charger is attached to the battery with no input supply voltage. If discharging under this condition must be kept to an absolute minimum, the sense divider can be referenced to the POWER INDICATE pin, Pin 7, instead of ground. In this manner the open collector off state of Pin 7 will prevent the divider resistors from discharging the battery when the input supply is removed.

Figures 4, 5 and 6 illustrate the UC2906's use in a different charging scheme. The dual step current charger is useful when a large string of series cells must be charged. The holding-charge state maintains a slightly elevated voltage across the batteries with the holding current,  $I_H$ . This will tend to guarantee equal charge distribution between the cells. The bulk-charge state is similar to that of the float charger with the exception that when  $V_{12}$  is reached, no over-charge state occurs since Pin 8 is tied high at all times. The current sense amplifier is used to regulate the holding current. In some applications a series resistor, or external buffering transistor, may be required at the current sense output to prevent excessive power dissipation on the UC2906.



### Figure 4. The UC2906 in a Dual Step Current Charger



$$1.) V_{12} = .95 V_{REF} \left( 1 + \frac{R_A}{R_C} + \frac{R_A}{R_D} \right)$$

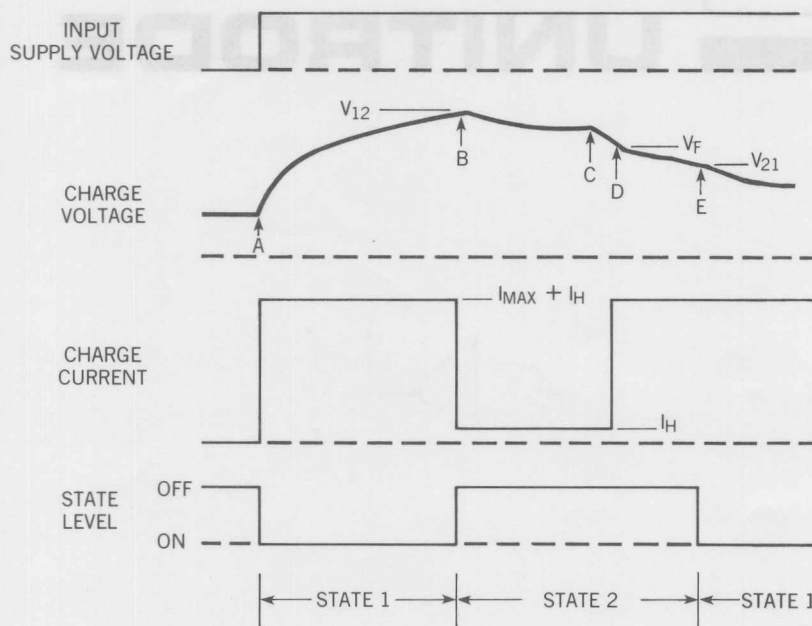
$$2.) V_F = V_{REF} \left( 1 + \frac{R_A}{R_C} \right)$$

$$3.) V_{21} = .9 V_F$$

$$4.) I_{MAX} = \frac{.25V}{R_{SM}}$$

$$5.) I_H = \frac{.025V}{R_{SH}}$$

Figure 5. State Diagram and Design Equations for the Dual Step Current Charger

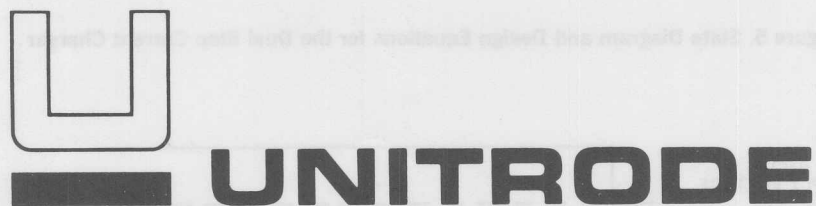


**Explanation: Dual Step Current Charger**

- A. Input power turns on, battery charges at a rate of  $I_H + I_{MAX}$ .
- B. Battery voltage reaches  $V_{12}$  and the voltage loop switches to the lower level  $V_F$ . The battery is now fed with the holding current  $I_H$ .
- C. An external load starts to discharge the battery.

- D. When  $V_F$  is reached the charger will supply the full current  $I_{MAX} + I_H$ .
- E. The discharge continues and the battery voltage reaches  $V_{21}$  causing the charger to switch back to state 1.

Figure 6. Typical Charge Cycle: UC2906 Dual Step Current Charger



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